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Novel and traditional anthropometric indices to identify metabolic syndrome and metabolically healthy obesity in obese women

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ABSTRACT

Aims: Traditional anthropometric indices may be inadequate for distinguishing obese individuals with low metabolic risk or those who are metabolically healthy. Therefore, newer, innovative indices may offer improved diagnostic accuracy. Current study aims to evaluate effectiveness of both traditional and novel anthropometric indices in identifying metabolic syndrome (MetS) and assessing metabolic risk factors such serum uric acid (SUA) and atherogenic index of plasma (AIP).

Methods: This was a retrospective study involving data of 292 obese women. The patients were separated into groups according to presence of MetS and their SUA and AIP levels. Predictive power was estimated using receiver operating characteristic curves, by comparing the area under the curve (AUC).

Results: Our results showed that all novel indices except the weight-adjusted waist index (WWI) had potential utility in diagnosing MetS. The lipid accumulation product (LAP) index had the highest AUC for MetS diagnosis, with a value of 0.832 (95% CI: 0.783–0.880). The abdominal volume index (AVI) and waist-to-height ratio (WHtR) showed the highest sensitivity (82.3%), while the waist-triglyceride index (WTI) had the highest specificity (89%).

Conclusion: Notably, both the visceral adiposity index (VAI) and LAP index achieved specificity and sensitivity values exceeding 70% and can be used in MetS screening of obese women. In contrast, the WWI was found to be statistically insufficient for defining MetS and distinguishing between SUA and AIP groups.

Keywords: Uric acid, atherogenic index of plasma, obesity, metabolic syndrome

INTRODUCTION

Obesity, which is one of the components of the metabolic syndrome (MetS), contributes to the development of diseases such as cardiovascular disease (CVD), diabetes, musculoskeletal disorders, malignancies and neuropsychiatric disorders, and reduces life expectancy and quality of life.[1] However, the development of obesity-related comorbidities cannot be explained simply by the degree of obesity, and there is considerable variability among individuals. The observation that some obese individuals have a significantly lower risk of cardiometabolic abnormalities has led to the concept of metabolically healthy obesity (MHO).[2] Although there is no clear definition, the diagnosis of MHO is made in the literature simply by excluding the diagnosis of MetS in obese individuals.[2,3] In turn, it is simply explained by relatively lower visceral fat, higher subcutaneous and peripheral fat, and preserved insulin sensitivity and beta cell function compared to metabolically unhealthy obese individuals.[3,4]

Traditional criteria used in diagnosing obesity, such as waist circumference (WC), body weight, or body-mass index (BMI), may not consistently correlate with visceral fat mass. Although these measures are commonly employed in clinical practice due to their accessibility, they may not be the ideal methods for evaluating visceral obesity.[5] This has prompted a need for anthropometric indices that more accurately correlate with visceral fat mass and central obesity and that are associated with various cardio-metabolic factors, particularly MetS. Recent studies have explored this need, introducing innovative indices such as the conicity index (CI), A body shape index (ABSI), body roundness index (BRI), abdominal volume index (AVI), visceral adiposity index (VAI), lipid accumulation product (LAP) index, triglyceride-glucose (TGI) index, waist-triglyceride index (WTI), the Clínica Universidad de Navarra-Body Adiposity Estimator (CUN-BAE) equation, and the weight-adjusted waist index (WWI), among others, in the literature. These indices have been evaluated both individually and in combination, with studies investigating their associations with various conditions, including MetS parameters malignancy, and mortality.[6-14] Remarkable findings have been reported, highlighting their potential clinical relevance. However, further investigation is required to determine whether these novel anthropometric

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indices are superior to traditional metrics in detecting MetS, particularly among overweight or obese individuals, and to identify which indices may most closely correlate with MetS.

Several clinical studies have reported serum uric acid (SUA), the product of purine catabolism, and the atherogenic index of plasma (AIP), a strong marker of atherogenic dyslipidemia, as predictive markers of cardiovascular outcomes.[15,16] Both SUA and AIP are closely associated with MetS and its components.[17-21] The relationship of these cardiovascular risk markers, which have been strongly associated with MetS and CVD, to new anthropometric indices has not been clearly established, and there is also a scientific gap in this area. Therefore, this study was designed to reveal the association of traditional and novel anthropometric indices with MetS, SUA and AIP in obese adult women.

METHODS

The study was conducted with the approval of the Yalova University School of Medicine Non-invasive Clinical Researches Ethics Committee (Date: 08.01.2025, Decision No: 2024/362). All procedures adhered to ethical guidelines and the principles outlined in the Declaration of Helsinki. Since this was a retrospective study, written informed consent was not obtained from the patients.

The data of 292 adult female patients who were admitted to the obesity outpatient department with complaints of being overweight (BMI ≥30 kg/m^2) were retrospectively reviewed. Patients who were receiving medication for hyperuricemia or dyslipidemia, those older than 80 years or younger than 18 years, individuals with end-stage renal disease, pregnant patients, and those undergoing major surgery or hospitalized for any reason were excluded from the study.

The patients' age, height, weight, hip circumferences (HC), WC, and fasting biochemical values were recorded. Blood pressure was measured twice in the sitting position after at least five minutes of rest, and the mean values for systolic blood pressure (SBP) and diastolic blood pressure (DBP) were documented. Height and weight were measured with patients wearing minimal clothing and no shoes.

The diagnosis of MetS was established based on the modified National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III) criteria. However, for WC, the reference values of the Turkish Society of Endocrinology and Metabolism (≥90 cm for women) were applied. Accordingly, patients meeting at least three of the following criteria were classified as having MetS: increased WC, elevated serum triglyceride (TG) levels (≥150 mg/dl), reduced serum high-density lipoprotein cholesterol (HDL-Chol) levels (<50 mg/dl), elevated blood pressure (≥130/85 mmHg or a prior diagnosis/treatment for hypertension), and elevated fasting serum glucose levels (≥100 mg/dl or a prior diagnosis/treatment for diabetes).

The AIP was determined as the logarithmic ratio of TG to HDL-Chol.[16] As described in the literature, patients were divided into 3 groups according to their AIP value (AIP value less than <0.11, low risk; AIP value between 0.11 and 0.21, intermediate risk; and AIP value above 0.21, high risk of CVD).[16] Patients were divided into two groups according to their uric acid levels. The uric acid threshold was set at 6 mg/dl.

The formulas used for calculating anthropometric indices are provided in **Table 1**.

Insulin resistance was calculated using the homeostasis model assessment of insulin resistance (HOMA-IR) formula=insulin (U/L)×glucose (mg/dl)/405.

Table 1. Formulas used in the calculation of anthropometric indices

- BMI=weight (kg)/height (m)^2
- CI=WC (m)/[0.109√{weight (kg)/height (m)}]
- ABSI=WC (m)/[BMI$^{2/3}$(kg/m^2) height$^{1/2}$ (m)]
- BRI=364.2−365.5×{1−[(WC(m)/2π)/(0.5×height (m))]^2}$^{0.5}$
- VAI=WC (cm)/(36.58+(1.89*BMI))x(TG/0.81)x(1.52/HDL-C) where TG and HDL are expressed in mmol/L
- LAP (for females)=(WC (cm)−58)xTG (mmol/L))
- AVI=[2x(WC (cm))^2+0.7x(WC (cm)−HC (cm))^2]/1.000
- TMI: weight (kg)/height^3 (m)
- TGI=Ln [fasting TG (mg/dl)×fasting glucose (mg/dl)]/2,
- WTI=Ln [fasting triglyceride (mg/dl)×WC (cm)/2]
- CUN-BAE was calculated using the equation body fat percentage (BF%)=−44.988+(0.503×age)+(10.689×sex)+(3.172×BMI)-(0.026×BMI^2)+(0.181×BMI×sex)−(0.02×BMI×age)−(0.005×BMI^2×sex)+(0.00021×BMI^2×age), where age is measured in years, and sex was codified as 0 for men and 1 for women
- WWI=WC (cm)/√weight (kg)
- WHR=WC (cm)/HC (cm)
- WHtR=WC (cm)/height (cm)

BMI: Body-mass index, CI: Conicity index, ABSI: A body shape index, BRI: Body roundness index, VAI: Visceral adiposity index (for females), LAP index: Lipid accumulation product index (for females), AVI: Abdominal volume index, TMI: Triponderal mass index, TGI: Triglyceride glucose index, WTI: Waist-triglyceride index, CUN-BAE: The Clínica Universidad de Navarra-Body Adiposity Estimator, WWI: Weight adjusted waist index, WHR: Waist to hip ratio, WHtR: Waist to height ratio, WC: Waist circumference, HC: Hip circumference, HDL-Chol: High density lipoprotein cholesterol, TG: Triglyceride

Statistical Analysis

The data analyses were performed using the Statistical Package for the Social Sciences for Windows, version 25.0 (SPSS, Chicago, IL, USA). The Kolmogorov-Smirnov test was employed to assess the normality of variable distributions. Descriptive statistics were presented as mean±standard deviation for normally distributed variables and as median with interquartile range for non-normally distributed variables. For group comparisons, the Student's t-test was used for normally distributed data, while the Mann-Whitney U test was applied to non-normally distributed data. Comparisons involving more than two groups were conducted using one-way ANOVA for parametric data and the Kruskal-Wallis test for nonparametric data. Correlation analyses were performed using the Spearman correlation test for nonparametric variables. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 292 obese women, with a mean age of 41.8 years, were enrolled in this study. The mean BMI of the participants was 37.96 kg/m^2, while the mean WC and HC were 106.4 cm and 127.4 cm, respectively. MetS was identified in 65.8% of the participants (n=192).

As expected, significant differences were observed in HDL-Chol, TG, AIP, glucose levels, glycosylated hemoglobin, HOMA-IR, SUA, SBP, DBP, WC, HC, and BMI when participants were stratified based on the presence of MetS.

Statistically significant differences were noted between the two groups for all evaluated anthropometric indices, except for the WWI. Detailed data are presented in Table 2.

Table 3 presents the results of the receiver operating characteristic (ROC) analysis, which was conducted to evaluate the predictive performance of anthropometric indices and equations for MetS in obese women. The analysis revealed that, except for the WWI, all equations and indices had an area under the curve (AUC) above 0.5 with statistically significant p-values, indicating their potential utility in diagnosing MetS in obese women. Among these, the highest AUC was observed for the LAP index. The highest sensitivity was found for the AVI and WHtR at 82.3%, whereas the highest specificity was observed for the WTI at 89%. The highest Youden index values were recorded for WTI (0.541) and LAP (0.536). Notably, both the VAI and LAP index demonstrated specificity and sensitivity exceeding 70%.

Bivariate correlation analysis between anthropometric indices, equations, and MetS status revealed the strongest correlation with the LAP index, while no significant correlation was found for WWI (Table 4).

Participants were further categorized into three groups based on their AIP, a key indicator of the atherogenic lipid profile that is closely associated with MetS. Statistically significant differences were observed between the groups in terms of CI, ABSI, VAI, LAP index, TGI, VTI, and WHR. However, no significant differences were found between the groups in classical anthropometric indices such as WC, HC, and BMI, nor in indices such as the BRI, AVI, TMI, CUN-BAE, WWI, and WHtR (Table 5).

Similarly, when participants were categorized into two groups based on SUA levels, no significant differences were observed in HC and WWI. However, statistically significant differences were found between the groups across all other examined

Table 2. Demographic, clinic and laboratory features of subjects according to presence of metabolic syndrome

Parameters	Patients without metabolic syndrome n=100	Patients with metabolic syndrome n=192	p-value
Age (years)**	42 (32-47.8)	44 (36-50)	0.051
T-Chol (mg/dl) *	192.5±35.7	197.3±37.1	0.288
HDL-Chol (mg/dl) **	53 (47-60.8)	46.5 (41-53)	<0.001
LDL-Chol (mg/dl) **	123.5 (105-139.8)	128 (109-146.5)	0.215
TG (mg/dl) **	104.5 (77-132)	153 (111.3-199.8)	<0.001
AIP*	-0.075±0.190	0.156±0.218	<0.001
Glucose (mg/dl) **	89.5 (85-95)	96 (89-107)	<0.001
HbA1c (%) **	5.4 (5.2-5.6)	5.7 (5.5-6.1)	<0.001
HOMA-IR**	2.31 (1.47-3.41)	3.85 (2.41-5.92)	<0.001
Creatinine (mg/dl) **	0.75 (0.71-0.81)	0.76 (0.69-0.82)	0.872
Uric acid (mg/dl) **	4.8 (3.9-5.3)	5 (4.3-5.8)	0.009
TSH (mIU/L) **	2.31 (1.51-3.31)	2.28 (1.49-3.25)	0.897
Systolic BP (mmHg)**	110 (110-120)	120 (120-140)	<0.001
Diastolic BP (mmHg)**	70 (60-77.5)	80 (70-90)	<0.001
Waist circumference (cm) **	99 (95-106)	109 (102.3-116)	<0.001
Hip circumference (cm) **	124.5 (118.3-130)	127 (121-136)	0.06
BMI (kg/m^2) **	36.07 (32.5-38.7)	38.53 (35.5-41.8)	<0.001
CI**	1.217 (1.171-1.253)	1.274 (1.230-1.319)	<0.001
ABSI*	0.073±0.005	0.076±0.004	<0.001
BRI**	5.973 (5.494-6.417)	6.642 (6.107-7.181)	<0.001
VAI**	1.523 (1.071-2.051)	2.678 (1.956-3.606)	<0.001
LAP index**	48.637 (34.652-62.930)	90.557 (64.110-117.190)	<0.001
AVI**	20.153 (18.587-22.781)	23.992 (21.3415-27.333)	<0.001
TMI**	22.523 (19.987-24.601)	23.996 (21.871-26.058)	<0.001
TGI**	8.449 (8.133-8.703)	8.871 (8.629-9.288)	<0.001
WTI*	8.522±0.3945	9.038±0.457	<0.001
CUN-BAE*	48.006±4.323	50.431±3.963	<0.001
WWI*	0.549±0.049	0.555±0.0509	0.327
WHR*	0.804±0.0592	0.853±0.054	<0.001
WHtR**	0.619 (0.592-0.664)	0.676 (0.640-0.720)	<0.001

T-Chol: Total cholesterol, HDL-Chol: High density lipoprotein cholesterol, LDL-Chol: Low density lipoprotein cholesterol, TG: Triglyceride, AIP: Atherogenic index of plasma, HbA1c: Glycosylated hemoglobin, HOMA-IR: Homeostatic model assessment for insulin resistance, TSH: Thyroid-stimulating hormone, BP: Blood pressure, BMI: Body-mass index, CI: Conicity index, ABSI: A body shape index, BRI: Body roundness index, VAI: Visceral adiposity index (for females), LAP index: Lipid accumulation product index (for females), AVI: Abdominal volume index, TMI: Tripondderal mass index, TGI: Triglyceride glucose index, WTI: Waist-triglyceride index, CUN-BAE: The Clínica Universidad de Navarra-Body Adiposity Estimator, WWI: Weight adjusted waist index, WHR: Waist to hip ratio, WHtR: Waist to height ratio, * Independent sample t test (mean±SD), ** Mann-Whitney U test [median (IQR)].

Table 3. Area under the receiver operating curve for anthropometric indices in predicting of metabolic syndrome in obese women

Parameters	AUC (95% CI)	p value	Cut-off value	Sensitivity	Specificity	Youden index
CI	0.749 (0.69-0.808)	<0.001	1.263	57.8	85	0.428
ABSI	0.673 (0.608-0.738)	<0.001	0.0755	51	75	0.260
BRI	0.715 (0.651-0.778)	<0.001	6.088	76	63	0.390
VAI	0.800 (0.748-0.851)	<0.001	2.063	72.4	77	0.494
LAP index	0.832 (0.783-0.880)	<0.001	63.201	77.6	76	0.536
AVI	0.749 (0.689-0.808)	<0.001	20.683	82.3	57	0.393
TMI	0.641 (0.574-0.709)	<0.001	23.833	54.7	69	0.237
TGI	0.801 (0.751-0.852)	<0.001	8.730	67.7	79	0.467
WTI	0.810 (0.759-0.86)	<0.001	8.904	65.1	89	0.541
CUN-BAE	0.665 (0.599-0.732)	<0.001	49.821	60.9	66	0.269
WWI	0.528 (0.458-0.598)	0,432	0.537	65.6	42	0.076
WHR	0.735 (0.675-0.794)	<0.001	0.819	76	60	0.360
WHtR	0.750 (0.69-0.81)	<0.001	0.632	82.3	58	0.403
BMI	0.661 (0.595-0.727)	<0.001	36.947	64.6	64	0.286

AUC: Area under curve, 95% CI: Asymptotic 95% confidence interval, lower and upper bound, CI: Conicity index, ABSI: A body shape index, BRI: Body roundness index, VAI: Visceral adiposity index (for females), LAP index: Lipid accumulation product index (for females), AVI: Abdominal volume index, TMI: Triponderal mass index, TGI: Triglyceride glucose index, WTI: Waist-triglyceride index, CUN-BAE: The Clínica Universidad de Navarra-Body Adiposity Estimator; WWI: Weight adjusted waist index, WHR: Waist to hip ratio, WHtR: Waist to height ratio, BMI: Body-mass index

Table 4. Bivariate correlation results between metabolic syndrome and anthropometric indices

Parameters	Correlation coefficient (r_s)	p-value
CI	0.409**	<0.001
ABSI	0.284**	<0.001
BRI	0.353**	<0.001
VAI	0.492**	<0.001
LAP index	0.545**	<0.001
AVI	0.409**	<0.001
TMI	0.232**	<0.001
TGI	0.495**	<0.001
WTI	0.509**	<0.001
CUN-BAE	0.272**	<0.001
WWI	00.046	0.433
WHR	0.386**	<0.001
WHtR	0.411**	<0.001
BMI	0.265**	<0.001

CI: Conicity index, ABSI: A body shape index, BRI: Body roundness index, VAI: Visceral adiposity index (for females), LAP index: Lipid accumulation product index (for females), AVI: Abdominal volume index, TMI: Triponderal mass index, TGI: Triglyceride glucose index, WTI: Waist-triglyceride index, CUN-BAE: The Clínica Universidad de Navarra-Body Adiposity Estimator, WWI: Weight adjusted waist index, WHR: Waist to hip ratio, WHtR: Waist to height ratio, BMI: Body-mass index

indices and equations, including classical anthropometric indices such as WC and BMI (Table 6).

DISCUSSION

Considering the prevalence of obesity and its dramatic increase in recent decades, a realistic approach to reducing the medical and socioeconomic costs associated with obesity treatment may be to prioritize high-risk patients who would benefit most from weight loss interventions. Such risk-stratified obesity management will require better methods and strategies for quantifying the risk of obesity-related morbidity and mortality.

The relationship between traditional and novel anthropometric indices and MetS has been extensively investigated in the general population.[6-10]; however, studies focusing specifically on the obese population remain limited. In an study specifically using BRI and ABSI, BRI demonstrated the best ability to detect IR in the overweight and obese population, while only BRI and WC, but not ABSI, could significantly assess the presence of MetS.[11] The study conducted by Rasaei et al.[12] using ABSI and body composition analyzer data along with classical indices such as BMI, WC and neck circumference, they suggest that the largest area under the ROC curve was related to neck circumference, WC, fat mass and BMI not ABSI. In a study by Sagun et al.[22] using traditional indices and body composition analyzer, WC was not associated with MetS in overweight and obese individuals, but interestingly, forearm circumference was reported to be associated with MetS. In our detailed literature review, we did not find a study in which a wide range of innovative/novel anthropometric indices were used specifically in obese patients to define MetS or MHO. According to our results, the LAP index is the marker with the highest AUC value and VAI, which has both sensitivity and specificity rates above 70% together with LAP index, are indicies that may be successfully used to define MetS and differentiate MHO patients in obese individuals.

Circulating lipoprotein particles can be divided into many categories according to their size and density. Small dense LDL is more reactive to oxidation and is more closely associated with plaque formation, which causes atherosclerotic lesions, than large dense LDL. AIP is positively associated with small dense LDL, which has been shown to have a high predictive value for CVD.[16] AIP has a well-established link between MetS, obesity and BMI.[17-19] However, a specific study

Table 5. Demographic, clinic and laboratory features of subjects according to PAI groups

Parameters	Low risk group (AIP<0.11) (n=157)	Intermediate risk group (AIP=0.11-0.21) (n=54)	Increased risk group (AIP>0.21) (n=81)	p value
Age (years)**	43 (34.5-50)	41 (33-48.3)	43 (35.5-48.5)	0.610
T-Chol (mg/dl) *	193±32.5	188.5±33.5	205.5±43.9	0.012
HDL-Chol (mg/dl) *	54.0±9.6	44.8±6.2	44.7±7.8	<0.001
LDL-Chol (mg/dl) *	123.8±25.3	123.7±29.0	137.0±29.4	0.001
TG (mg/dl) **	100 (80-124)	148 (131-160.3)	220 (189-267)	<0.001
AIP**	-0.082(-0.197-0.030)	0.162 (0.135-0.185)	0.316 (0.251-0.413)	-
Glucose (mg/dl) **	94 (87-101)	91 (87-100.3)	95 (88-110)	0.211
HbA1c (%) **	5.5 (5.3-5.85)	5.6 (5.2-5.9)	5.7 (5.4-6.15)	0.021
HOMA-IR**	2.80 (1.73-4.26)	3.41 (2.12-4.58)	4.40 (2.38-6.78)	<0.001
Creatinine (mg/dl) **	0.76 (0.71-0.82)	0.75 (0.68-0.82)	0.76 (0.7-0.83)	0.853
Uric Acid (mg/dl) **	4.7 (3.8-5.2)	5.1 (4.5-5.8)	5.4 (4.6-6.2)	<0.001
TSH (mIU/L) **	2.41 (1.51-3.28)	2.37 (1.535-3.17)	2.11 (1.39-3.37)	0.677
Systolic BP (mmHg)**	120 (110-140)	120 (110-130)	120 (110-130)	0.916
Diastolic BP (mmHg)**	80 (70-80)	80 (67.5-80)	80 (70-80)	0.807
Waist circumference (cm)**	105 (97.5-111.5)	105 (100-114)	107 (100.5-114)	0.086
Hip circumference(cm) **	127 (120.5-135.5)	124 (120-133.3)	126 (120-135)	0.453
BMI (kg/m^2) **	37.4 (34.1-40.8)	37.5 (34.5-40.5)	38.1 (34.1-41.3)	0.868
CI**	1.24 (1.20-1.28)	1.26 (1.21-1.31)	1.28 (1.23-1.33)	0.001
ABSI*	0.074±0.004	0.075±0.004	0.076±0.004	0.003
BRI**	6.28 (5.78-6.94)	6.39 (5.90-7.11)	6.58 (6.04-7.06)	0.117
VAI**	1.532 (1.150-1.980)	2.687 (2.542-2.865)	3.939 (3.377-4.961)	<0.001
LAP index**	52.4756 (37.731-66.797)	78.059 (68.688-96.041)	124.517 (97.969-155.192)	<0.001
AVI**	22.33 (19.45-25.33)	22.34 (20.25-26.36)	23.23 (20.8-26.16)	0.116
TMI**	23.31 (20.99-25.69)	22.94 (20.79-25.93)	23.95(21.07-25.58)	0.853
TGI**	8.48 (8.23-8.67)	8.82 (8.74-8.93)	9.33(9.05-9.58)	<0.001
WTI**	8.58 (8.30-8.77)	8.98 (8.84-9.08)	9.41 (9.22-9.57)	<0.001
CUN-BAE*	49.57±4.18	49.42±4.19	49.78±4.44	0.887
WWI*	0.55±0.048	0.56±0.046	0.56±0.056	0.116
WHR**	0.83 (0.797-0.85)	0.84 (0.81-0.88)	0.86(0.81-0.89)	<0.001
WHtR**	0.65 (0.61-0.70)	0.66 (0.62-0.71)	0.67 (0.63-0.71)	0.087

T-Chol: Total cholesterol, HDL-Chol: High density lipoprotein cholesterol, LDL-Chol: Low density lipoprotein cholesterol, TG: Triglyceride, AIP: Atherogenic index of plasma ; HbA1c: Glycosylated hemoglobin, HOMA-IR: Homeostatic model assessment for insulin resistance, TSH: Thyroid-stimulating hormone, BP: Blood pressure, BMI: Body-mass index, CI: Conicity index, ABSI: A body shape index, BRI: Body roundness index, VAI: Visceral adiposity index (for females), LAP index: Lipid accumulation product index (for females), AVI: Abdominal volume index, TMI: Triponderal mass index, TGI: Triglyceride glucose index, WTI: Waist-triglyceride index, CUN-BAE: The Clinica Universidad de Navarra-Body Adiposity Estimator, WWI: Weight adjusted waist index, WHR: Waist to hip ratio, WHtR: Waist to height ratio. * One way ANOVA test (Mean±SD), ** Kruskal-Wallis test [median (IQR)].

evaluating the AIP among anthropometric indices, especially new innovative anthropometric indices, could not be identified despite an extensive literature search. Considering the results of our study, it should be noted that, after excluding innovative anthropometric indices using triglyceride-based data, the WHR, ABSI and CI created a significant difference between AIP risk groups, whereas traditional parameters such as BMI and WC parameters did not create a significant difference. When the indices that use TG in the calculation are included in the evaluation, the LAP index, VAI, TGI and WTI, in addition to WHR, ABSI and CI, also make a significant difference in the evaluation of AIP and we believe that these indices can be used in clinical processes.

Numerous studies have shown a significant correlation between serum UA, the end product of purine catabolism, and components of the MetS such as atherogenic lipid profile, obesity and hypertension.[20,21] Many possible reasons have been proposed to explain the association between hyperuricemia and MetS, such as reduced renal clearance or increased proximal tubular reabsorption of UA as a result of insulin resistance and elevated insulin levels, elevated leptin levels and fructose consumption, all of which are strongly associated with central obesity as the other components of MetS.[20,23] Studies on the relationship between anthropometric indices and SUA levels are relatively more than those conducted with AIP. The study by Hongwei et al.[24] used LAP, TGI, ABSI, cardiometabolic index, VAI, and BRI, and reported that the capacity of LAP and TGI indexes were better than other anthropometric indexes in predicting hyperuricemia. In a large sample study by Chen et al.[25], BMI, WC, BRI, WHtR, LAP, VAI, TGI, WTI, and WWI were all significantly associated with hyperuricemia. In the total population, WTI, and when the female and male populations were evaluated separately, LAP had the highest predictive power. In studies

Table 6. Demographic, clinic and laboratory features of subjects according to UA groups

Parameters	Group I Patients with normal uric acid values UA<6 (n =240)	Group II Patients with high uric acid values UA≥6 (n = 52)	p value
Age (years)**	43 (34.3-49)	43.5 (35-51.8)	0.577
T-Chol (mg/dl) **	189 (169-214)	194 (172.25-227.8)	0.275
HDL-Chol (mg/dl) **	50 (43-57)	47.5 (41-51.8)	0.046
LDL-Chol (mg/dl) **	125 (107.3-142)	130 (106.5-151.3)	0.288
TG (mg/dl) *	127 (93.3-169)	160.5 (103.8-229)	0.004
AIP**	0.055±0.230	0.178±0.238	0.001
Glucose (mg/dl) **	93 (87-101)	96.5 (88.3-107.8)	0.114
HbA1c (%) **	5.6 (5.3-5.9)	5.75 (5.4-6.2)	0.048
HOMA-IR**	3.12 (1.90-4.85)	4.20 (2.84-5.60)	0.010
Creatinine (mg/dl) **	0.75 (0.7-0.81)	0.78 (0.72-0.85)	0.152
Uric acid (mg/dl) **	4.7 (3.9-5.2)	6.5 (6.2-7.2)	-
TSH (mIU/L) **	2.32 (1.51-3.34)	2.275 (1.52-3.18)	0.880
Systolic BP (mmHg)**	120 (110-130)	120 (110-140)	0.195
Diastolic BP (mmHg)**	80 (70-80)	80 (70-80)	0.565
Waist circumference (cm)**	105 (99-112)	111.5 (104.3-116.8)	<0.001
Hip circumference(cm)**	126 (120-133)	127 (122-136.8)	0.167
BMI (kg/m^2)*	37.4 (33.7-40.4)	38.7 (36.6-44.9)	0.010
CI*	1.247±0.074	1.286±0.068	0.001
ABSI**	0.074±0.004	0.076±0.004	0.023
BRI**	6.264 (5.793-6.961)	6.756 (6.167-7.713)	0.001
VAI**	2.132 (1.409-2.905)	2.928 (1.949-4.136)	<0.001
LAP index**	67.226 (45.868-97.416)	98.257 (62.027-135.175)	<0.001
AVI**	22.316 (19.855-25.366)	24.938 (22.154-27.379)	<0.001
TMI**	23.156 (20.761-25.519)	24.365 (22.451-28.334)	0.013
TGI**	8.713 (8.411-8.970)	8.908 (8.511-9.375)	0.004
WTI*	8.812±0.485	9.092±0.507	<0.001
CUN-BAE*	49.296±4.195	51.003±4.216	0.008
WWI**	0.551±0.0500	0.558±0.0517	0.378
WHR**	0.832 (0.792-0.869)	0.862(0.823-0.889)	<0.001
WHtR**	0.651 (0.611-0.701)	0.692(0.653-0.736)	<0.001

T-Chol: Total cholesterol, HDL-Chol: High density lipoprotein cholesterol, LDL-Chol: Low density lipoprotein cholesterol, TG: Triglyceride, AIP: Atherogenic index of plasma, HbA1c: Glycosylated hemoglobin, HOMA-IR: Homeostatic model assessment for insulin resistance, TSH: Thyroid-stimulating hormone, BP: Blood pressure, BMI: Body-mass index, CI: Conicity index, ABSI: A body shape index, BRI: Body roundness index, VAI: Visceral adiposity index (for females), LAP index: Lipid accumulation product index (for females), AVI: Abdominal volume index, TMI: Triponderal mass index, TGI: Triglyceride glucose index, WTI: Waist-triglyceride index, CUN-BAE: The Clínica Universidad de Navarra-Body Adiposity Estimator, WWI: Weight adjusted waist index, WHR: Waist to hip ratio, WHtR: Waist to height ratio. * Independent sample t test (Mean ± SD), ** Mann-Whitney U test [median (IQR)].

with a narrower parameter range, the association of TGI, ABSI, and BRI with SUA has been demonstrated.[26,27] In our study, except for WWI and HC, both traditional and novel anthropometric indices showed statistically significant differences between groups according to SUA levels.

Limitations

Our study has several limitations. First, our study is a cross-sectional study. The cross-sectional, retrospective nature of our study does not allow us to establish a cause-and-effect relationship. The fact that only women were included in our study to form a homogeneous group and that it was a single-center study makes it difficult to extrapolate the results to the general population.

CONCLUSION

All anthropometric indices, except for WWI, were found to be effective in defining MetS. The LAP index demonstrated the highest AUC value. Both the VAI and LAP indices exhibited specificity and sensitivity exceeding 70%. Additionally, these indices showed a significant distinction between SUA and AIP risk groups. Simple calculation of LAP index and VAI can be used to identify obese women at high metabolic risk. In contrast, WWI was found to be statistically insufficient for both defining MetS and differentiating between SUA and AIP groups.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was conducted with the approval of the Yalova University School of Medicine Non-invasive Clinical Researches Ethics Committee (Date: 08.01.2025, Decision No: 2024/362).

Informed Consent
Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process
Externally peer-reviewed.

Conflict of Interest Statement
The authors have no conflicts of interest to declare.

Financial Disclosure
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Author Contributions
All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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